RESEARCH DEPARTMENT

An aerial panel for medium power u.h.f. stations

TECHNOLOGICAL REPORT No. RA-24

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THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

AN AERIAL PANEL FOR MEDIUM POWER U.H.F. STATIONS

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AN AERIAL PANEL FOR MEDIUM POWER U.H.F. STATIONS

SUMMARY

A simple but effective aerial panel has been designed for use at medium power, horizontally-polarized u.h.f. stations. The panel is primarily intended for use in a triangular configuration and details of the performance of this arrangement are given.

1. INTRODUCTION

U.H.F. transmitting aerials may be broadly classed as either panel-type or pole-type. In the U.K. all aerials are required to transmit two or more programmes and must therefore have a branched distribution feeder system to achieve the required bandwidth. At the higher-powered stations the distribution feeder is bulky and is best accomodated inside configurations of panels. Stations having effective radiated powers (e.r.p.s) in the range 250 kW to 1 MW all use panel-type aerials. For the lower-powered stations the distribution feeder may be much smaller and can be built in or round a pole. Stations having e.r.p.s of 10 kW and less are mostly of this type. Stations having intermediate e.r.p.s, i.e. from 20 kW to 100 kW, could be of either type and this report is concerned with the design and use of an aerial panel for this range of e.r.p.s, with horizontal polarization.

2. BASIC REQUIREMENTS

An aerial panel is a vertical stack of radiating elements with a single feed point. It is therefore a convenient unit which simplifies the assembly of a large aerial and permits easy replacement should a fault occur. The height of the panel must be a compromise; the larger the panel the less complicated the distribution feeder for the whole aerial, but there would then be fewer control points for shaping the v.r.p.

A station having a maximum e.r.p. of 100 kW will be supplied with a vision transmitter rated at 10 kW peak power for each channel. Peak power is radiated during the synchronizing pulses; the maximum mean power, corresponding to a black picture, is 6·25 kW. The power of the associated sound transmission is 2 kW so that the maximum mean power per channel is 8·25 kW. Assuming ground feeder and network losses of 0·7 dB, main feeder losses of 1·6 dB and distribution feeder losses of 0·4 dB, the peak power reaching the aerial panels would be 5·4 kW per programme and the maximum mean power 4·5 kW. Allowing a further 1·5 dB for the maximum/mean ratio of the aerial h.r.p., the required mean gain with null-filling is about 11 dB. Thus an aerial length of about 16 wavelengths is required. If this were divided into panels four wavelengths high (referred to as '4λ panels') the control of the v.r.p. would be somewhat coarse and null-filling of the radiation pattern of the individual panels would be required. Accordingly it was decided to make a 2λ panel.

A 16λ aerial having three 2λ panels in each tier comprises a total of 24 panels. Since the maximum mean power reaching the aerial is 4·5 kW per channel, the mean power delivered to each panel for a four-channel aerial is 750 W. This assumes that each panel radiates the same power, i.e. that the v.r.p. null-filling is achieved by phase perturbation[1] rather than by a non-uniform amplitude distribution.

The E-plane radiation pattern of the panel must be tailored for the configuration to be used. A triangular arrangement of three panels per tier requires that the E-plane radiation pattern should fall to half amplitude at ± 60° from the direction of maximum radiation. For a square arrangement of four panels per tier the E-plane pattern should fall to half amplitude at ± 45°.

Finally, it is required that the individual panels should have a reasonable match to an impedance for which coaxial cables are available, preferably 50 ohms. The impedance match should hold over as wide a frequency range as possible in order to reduce the number of types of panel required to cover the broadcast frequency bands and to enable aerials to be provided without special measures for those stations having non-standard channel allocations.

3. THE AERIAL PANEL

3.1. Construction

The panel consists of four horizontal dipoles stacked vertically with a separation of one half wavelength at the mid-band frequency, to give a total radiating length of 2 wavelengths. The dipoles are mounted in front of a metallic sheet reflecting screen. Since the horizontal (E-plane) radiation pattern was required to be fairly broad, half-wave dipoles were chosen rather than the full-wave dipoles conventionally used in u.h.f. aerial panels.

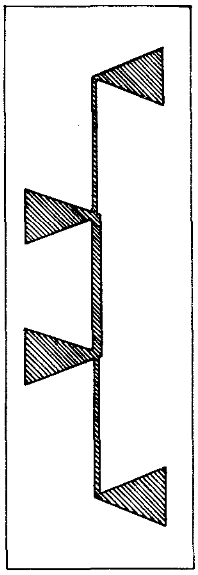

Fig. 1 - Basic printed pattern

The novelty of the panel lies in the method of fabrication of the dipoles and the interconnecting feeder.[2] Aerial panels in use at high-power stations require skilled assembly and setting up and are therefore expensive. In this panel, use is made of printed-circuit techniques to give components which are simply, but accurately, reproducible. One half of each dipole and an inter-connecting strip-line are printed in copper on a glass-fibre sheet as shown in Fig. 1. Two similar sheets are placed together with the copper cladding adjacent but with an air gap between them to form the array shown in Fig. 2. Connection is made to the mid-point of the strip-line by means of a Pawsey stub balun, as shown in Fig. 3. As the extreme dipoles are fed through a length of line which is physically one half-wavelength long, it is necessary to reverse connections as shown in Fig. 2. For the same reason it is desirable to keep the velocity of propagation of the strip transmission lines near to that of free space and this is achieved by the use of two thin laminates with an airspace between them.

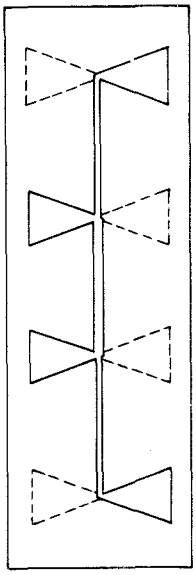

Fig. 2 - Assembly of two printed patterns to form aerial panel

3.2. Impedance

The shape of the radiating elements was chosen empirically with a view to the bandwidth required.[3] The impedance characteristic of the complete panel is a complicated function of the self impedances of the dipoles, the mutual impedances between the dipoles and their images in the reflecting screen and the frequency dependence of the lengths of strip-line. Accordingly the complete panel was constructed and the characteristic impedances of the inner and outer strip-lines adjusted to give the optimum match over a frequency band.

The initial matching was carried out with the radiating elements mounted 0·25λ from the reflecting screen and then investigated for greater spacings. For spacings up to about 0·3λ there was negligible degradation of match but for greater spacing some trimming was necessary and it proved more convenient on the prototype to achieve this by changing the spacing rather than the widths of the strip-lines.

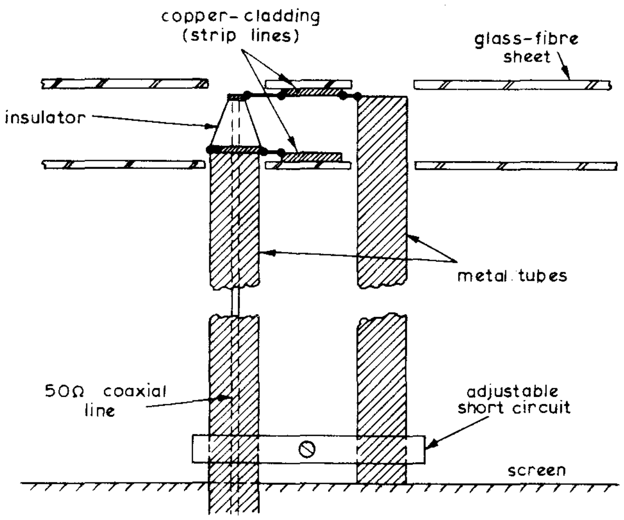

Fig. 3 - Construction of balun

The admittance characteristic of the final panel, measured in free space, is shown in Fig. 4. The effect of a 6·35 mm (0·25 in.) thick wall of glass-fibre mounted in front of the panel (to simulate a weather shield) is shown in Fig. 5.

3.3. Horizontal Radiation Pattern

The horizontal radiation pattern (h.r.p.) of the individual panel may be controlled by means of the spacing between the radiating elements and the reflecting screen. A spacing of 0·25λ gives an h.r.p. falling to approximately half amplitude at ± 45° and would be suitable for a configuration of 4 panels per tier. For the triangular configuration actually used a spacing between radiating elements and screen of 0·32λ at mid-band was chosen, giving the h.r.p.s shown in Fig. 6.

3.4. Vertical Radiation Pattern

The measured vertical radiation pattern (v.r.p.) of a single panel is shown in Fig. 7. At the highest frequency, the first side lobe is high but it should be possible to reduce the radiation in this direction when a number of panels are stacked.

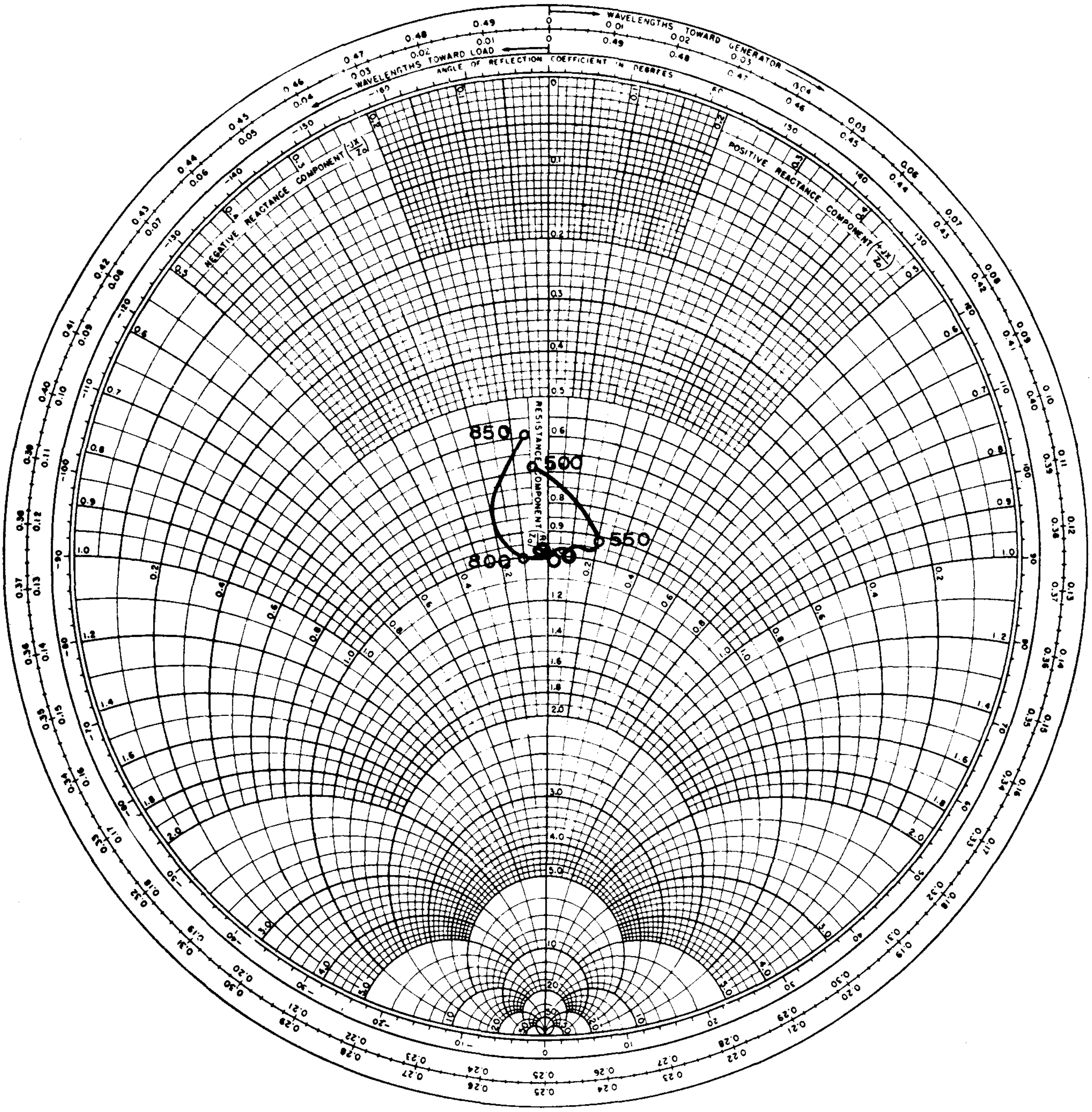

Fig. 4 - Admittance characteristic of single panel in free space
Dipole/reflector spacing 146 mm (5·75 in.) Numbers on curve are frequencies in MHz

3.5. Power Tests

The maximum power which could be made readily available was 300W. c.w., obtained by running two travelling-wave amplifiers in parallel. A single panel handled this power level satisfactorily. After prolonged operation in an ambient temperature of 25°C, the inner strip lines were slightly warm. Although some of this was evidently a result of conduction from the input cable in the Pawsey stub, it was decided that the gap between the laminate sheets should be doubled to 6mm (0·25 in.) in a production panel to give an increased margin of safety, with the strip-lines correspondingly increased in width.

4. THE H.R.P. OF ONE TIER OF PANELS

The requirement for h.r.p. uniformity is only one of many factors which influence the choice of configuration for the complete tier of panels. In general, the best h.r.p. uniformity will be obtained with radiating elements mounted on a support structure having as small a cross-section as possible.

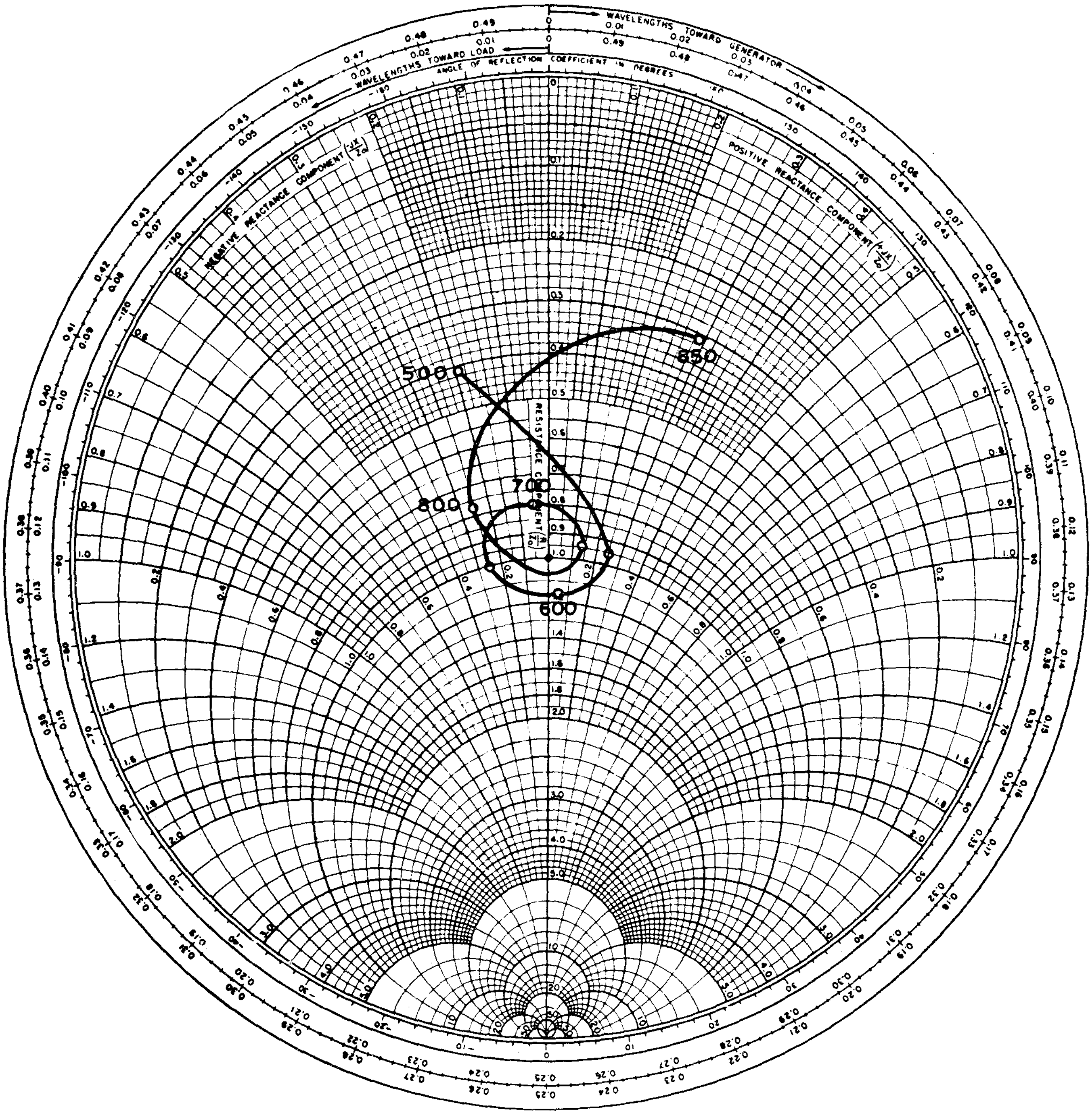

Fig. 5 - Admittance characteristic of single panel with simulated glass-fibre cylinder

Dipole/reflector spacing 146 mm (5·75 in.)   Numbers on curve are frequencies in MHz

However, this support structure will also be required to accommodate distribution transformers, distribution feeders and possibly large-diameter main feeders. Moreover, since this equipment must be accessible for maintenance, it would be an advantage if the interior of the support structure could be climbed. In addition, the support structure may be required in some circumstances to be a strong spine which carries both the aerial panels and a glass-fibre weather shield.

These considerations mean that the minimum side for a triangular support section is about 762 mm (30 in.) side if the inside is to be climbed; this presupposes small-diameter main and distribution feeders and a very careful layout. The support structure could be a little smaller if it is to be climbed on the outside, but a bigger space would then be required between the aerial panels and the weather shield.

At the start of this work it was intended that the aerial should be suitable for mounting inside a 1·52 m (5 ft.) diameter glass-fibre cylinder and measurements were made on the arrangement shown in Fig. 8 with two values of the side dimension. At a later stage structural reasons were advanced for the use of a 914 mm (3 ft.) diameter glass-fibre

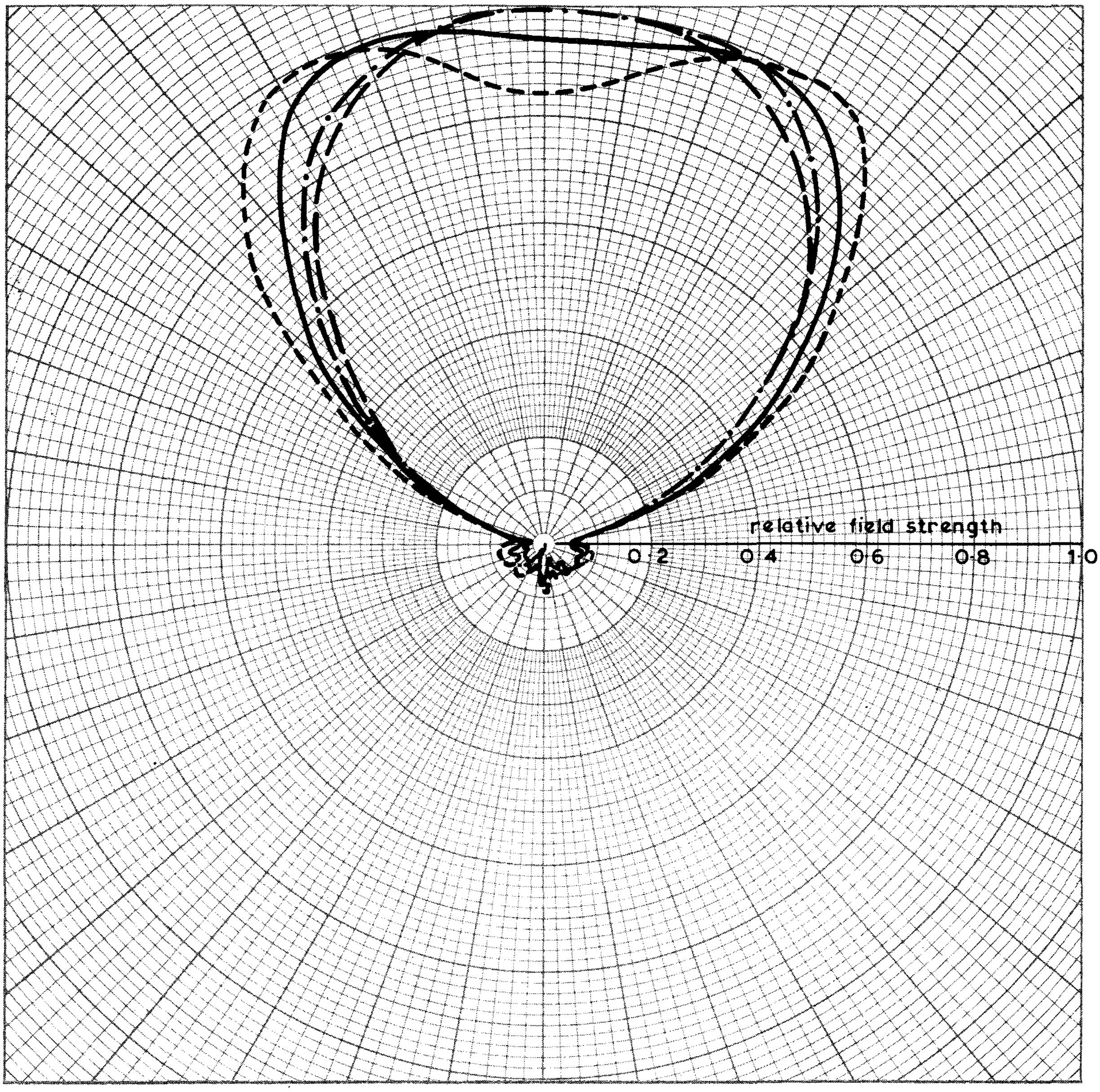

Fig. 6 - Horizontal radiation pattern of single panel in free space

Dipole/reflector spacing 146 mm (5·75 in.)

— — — — 500 MHz

— - — - — 600 MHz

———— 700 MHz

- - - - - 800 MHz

cylinder and the configuration shown in Fig. 9 was therefore investigated.

In Fig. 10 are h.r.p.s measured with the configuration of Fig. 8, a side dimension S of 762 mm (30 in.) and a dipole to reflector spacing of 143 mm (5·625 in.). These patterns are remarkably constant with frequency in the lower part of the frequency range but have a maximum/minimum ratio reaching 6 dB; this is greater than the limit usually specified (5 dB) although less than that actually achieved on some service aerials. The uniformity improved in the upper part of the frequency band and Fig. 11 shows that a maximum/minimum ratio not exceeding 3·5 dB was obtained over a useful frequency range.

With the cross-sectional dimensions given above, climbing room in the interior of the aerial

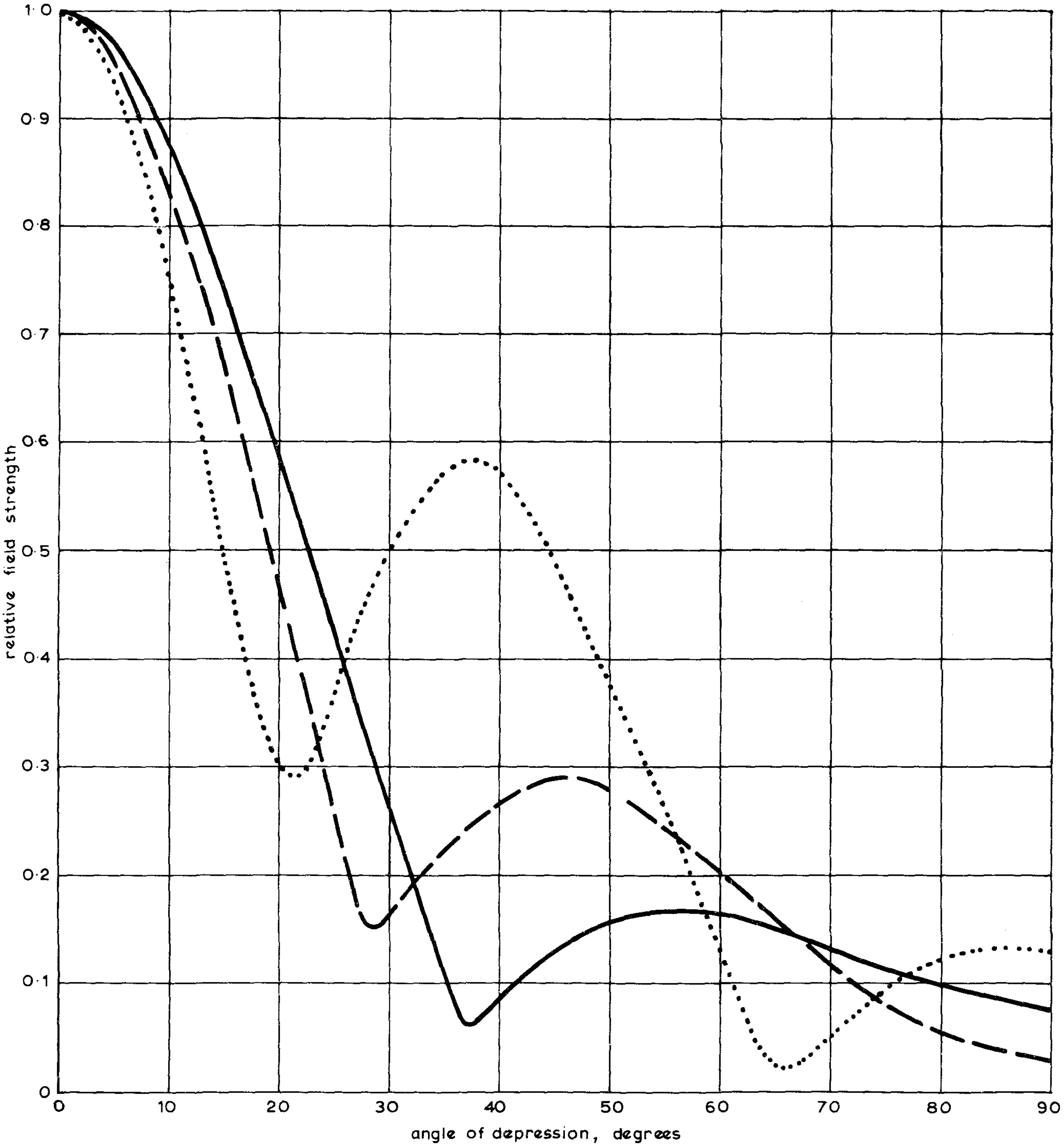

Fig. 7 - Vertical (H-plane) radiation pattern of single panel

——————— 550 MHz   — — — — — 650 MHz   •••••••••••••• 750 MHz would be very restricted and it was of interest to find out if acceptable results could be obtained with a spine that was somewhat larger but still capable of fitting inside a 1·52 m (5 ft.) glass-fibre cylinder.

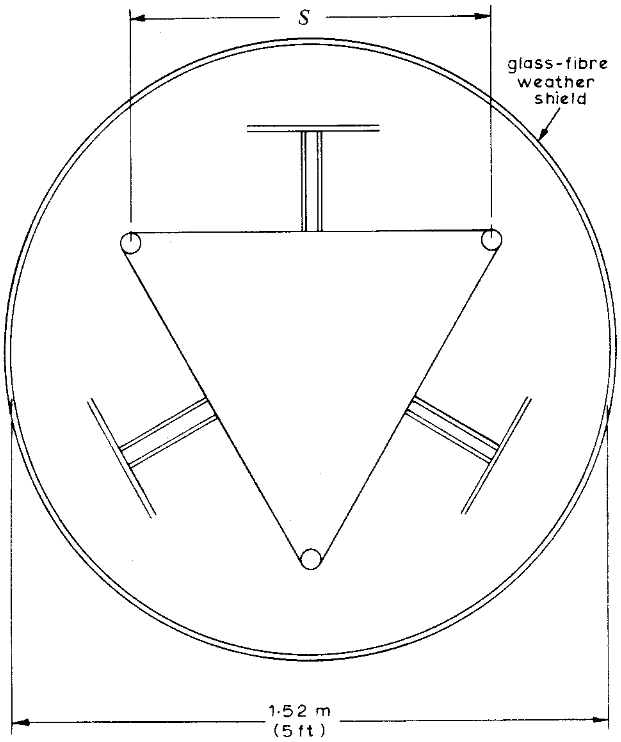

Fig. 8 - Panel configuration for use in 1·52m (5 ft) diameter glass-fibre weathershield

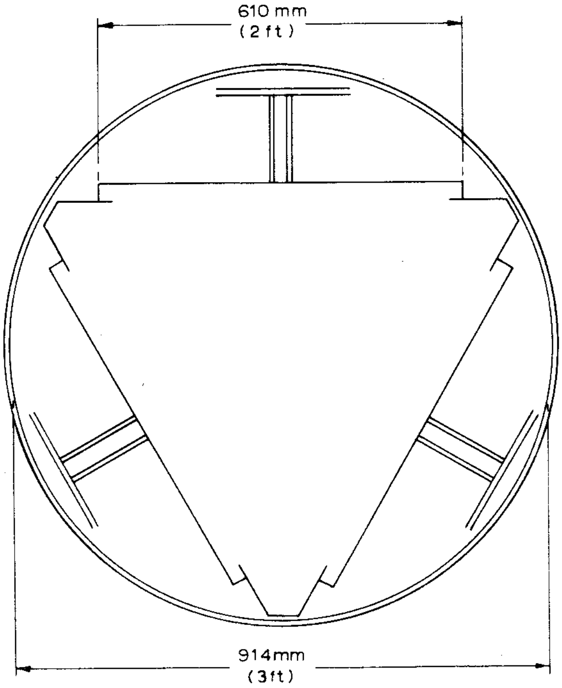

Fig. 9 - Panel configuration used in 914mm (3 ft) diameter glass-fibre weathershield

Accordingly the side dimension was increased to 914 mm (36 in.). At the same time the dipole/reflector spacing was increased to 165 mm (6·5 in.) in order to bring to a lower frequency the range of optimum uniformity, making it coincide with the frequency range giving the best admittance characteristic. The h.r.p.s, shown in Fig. 12, have a maximum/minimum ratio which does not exceed 4 dB over a frequency range of 1·25 : 1. This is more than sufficient for any of the standard four-channel allocations in Bands IV and V. The variation of field with frequency is also adequate, being no more than 3 dB over the frequency range shown in Fig. 12; the variation between channels would, of course, be less than this since the standard four-channel group covers a frequency span of only 88 MHz, or 1·19 : 1 at worst.

It is generally impossible to match an aerial panel over a frequency range of 1·25 : 1 to the degree required for a television transmitting aerial, so that some additional measure has to be taken to reduce aerial reflections. One possible method which has been widely used for v.h.f. and u.h.f. aerials is to feed the elements (or panels) of one tier in phase rotation. Unfortunately this has an effect on the horizontal radiation pattern. In order to determine whether this effect could be tolerated, the tier of panels was adapted for phase-rotational feeding (i.e. with phases of 0°, 120° and 240°*), the panels being offset in the triangular spine in order to bring into phase the contributions from adjacent panels on the intermediate bearing. The h.r.p.s obtained in free space and inside a section of 1·52 m (5 ft.) diameter glass-fibre cylinder are shown in Figs. 13 and 14 respectively. The maximum/minimum ratio has increased, particularly at the upper frequencies, and the frequency dependence is large. The patterns obtained when the aerial was mounted in the cylinder are generally unsatisfactory although it is reasonable to suppose that somewhat better results would be obtained with a thinner cylinder and with co-phased feeding.

The last configuration to be examined was that shown in Fig. 9. In this case the aerial was enclosed inside a 914 mm (3 ft.) glass-fibre cylinder. The measured patterns are shown in Fig. 15. The greatest maximum/minimum ratio obtained was 5·1 dB but as this includes some evident asymmetries in the feeds to the panels it is reasonably certain that the target specification of 5·0 dB would be met with ease on a properly engineered aerial. In view of this, no attempt was made to determine the panel/reflector spacing or the method of mounting the panels to give the best uniformity.

* The feed cables were actually cut for phases of 0° 120° and 60°, the last panel being inverted to give 240°.

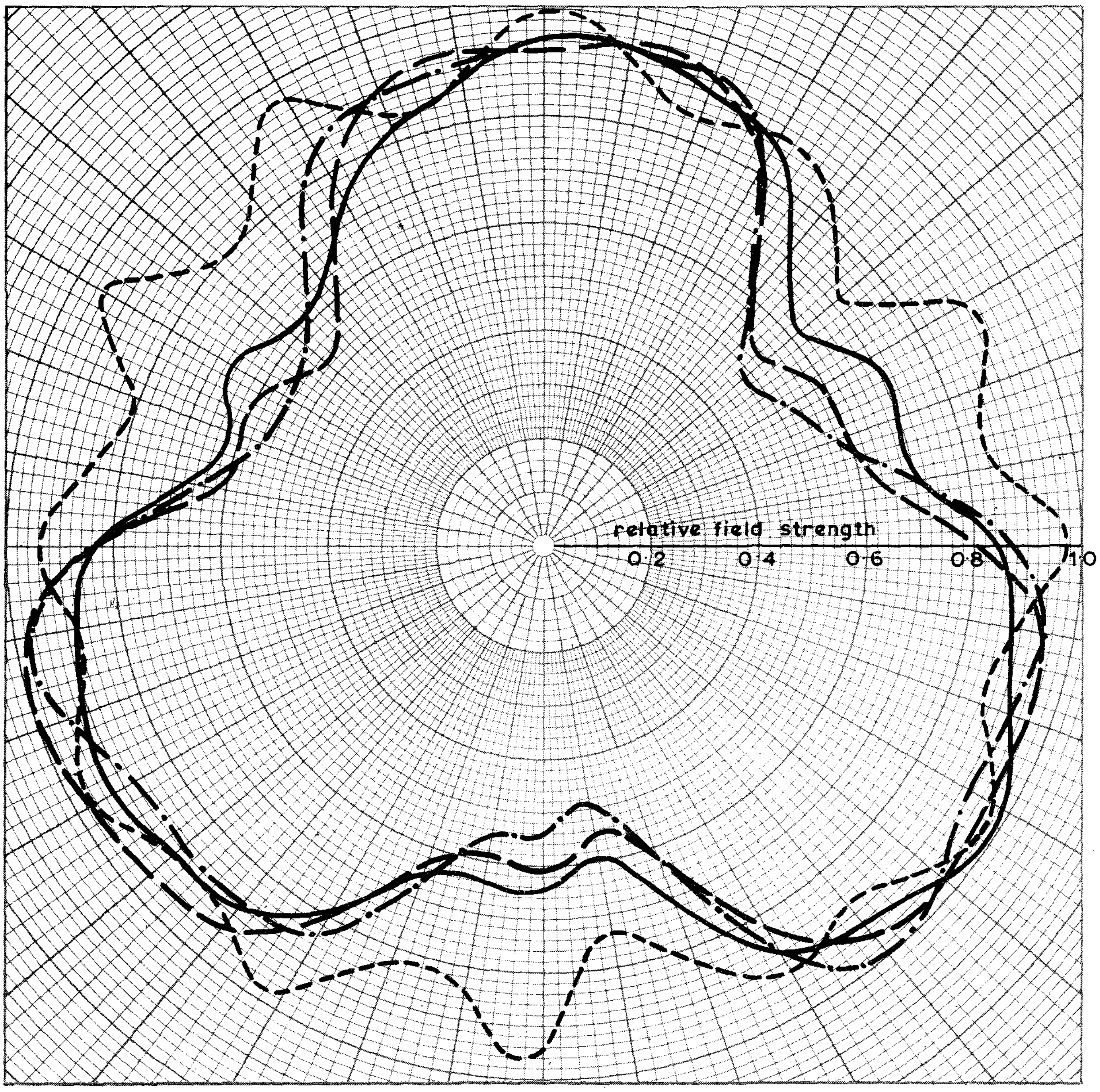

Fig. 10 - Horizontal radiation pattern of one tier of three panels in free space; 760 mm (30 in.) side dimension

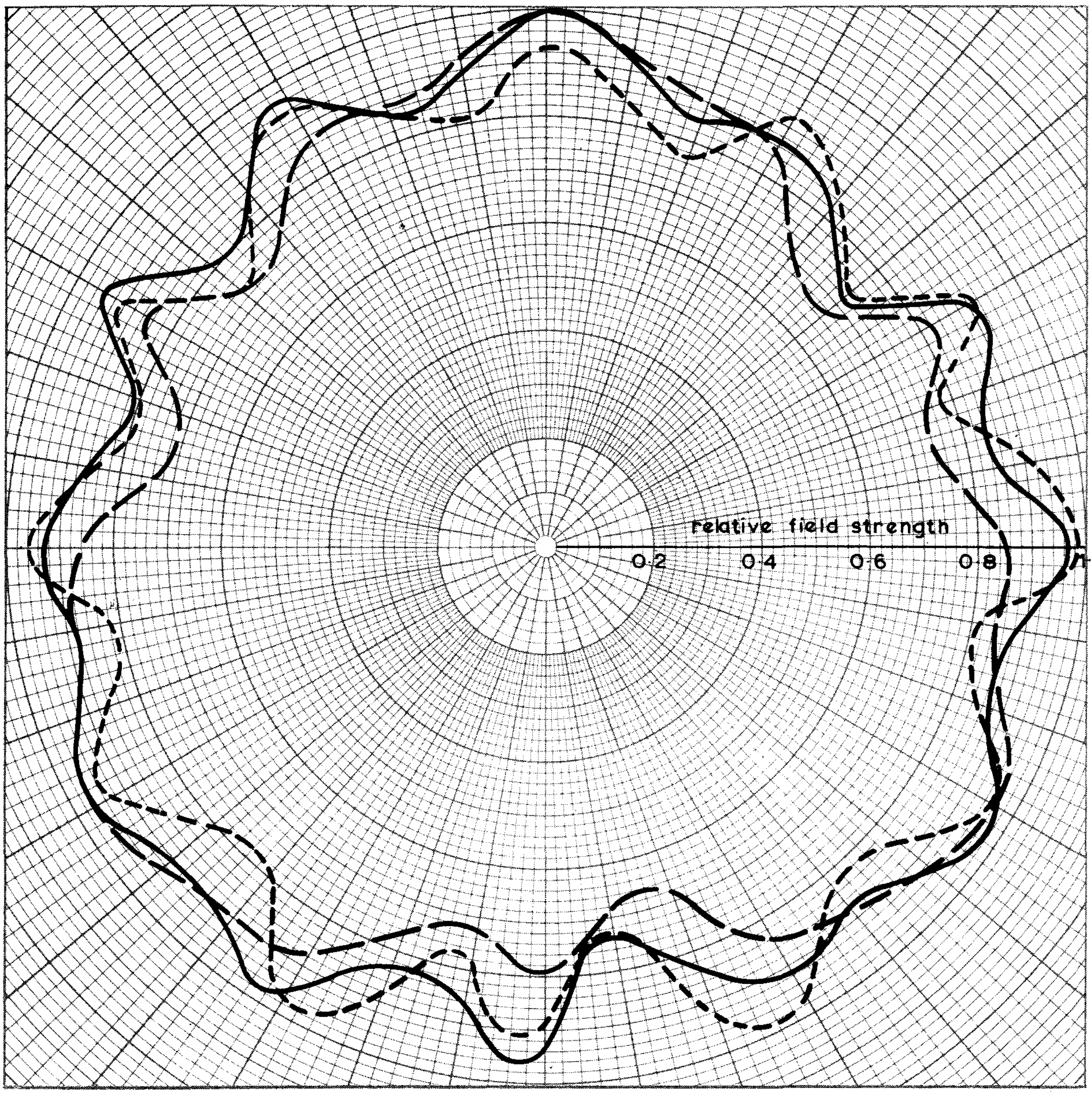

Fig. 11 - Horizontal radiation pattern of one tier of three panels in free space; 760 mm (30 in.) side dimension (frequency range for best uniformity)

— — — — 750 MHz ———— 800 MHz - - - - - - 850 MHz

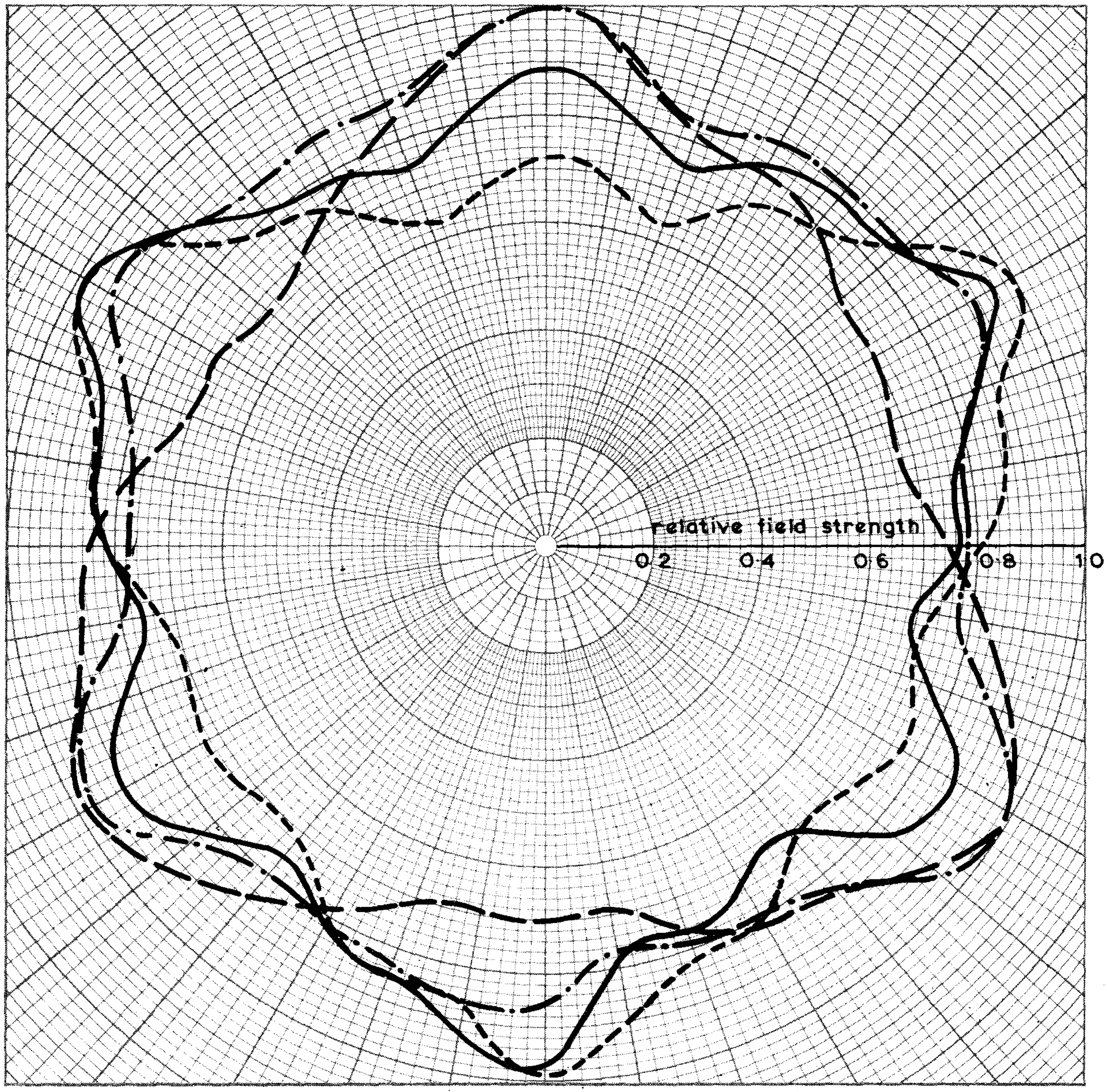

Fig. 12 - Horizontal radiation pattern of one tier of three panels in free space; 914 mm (3 ft) side dimension

— — — — 600 MHz — · — · — 650 MHz ———— 700 MHz - - - - - - - - 750 MHz

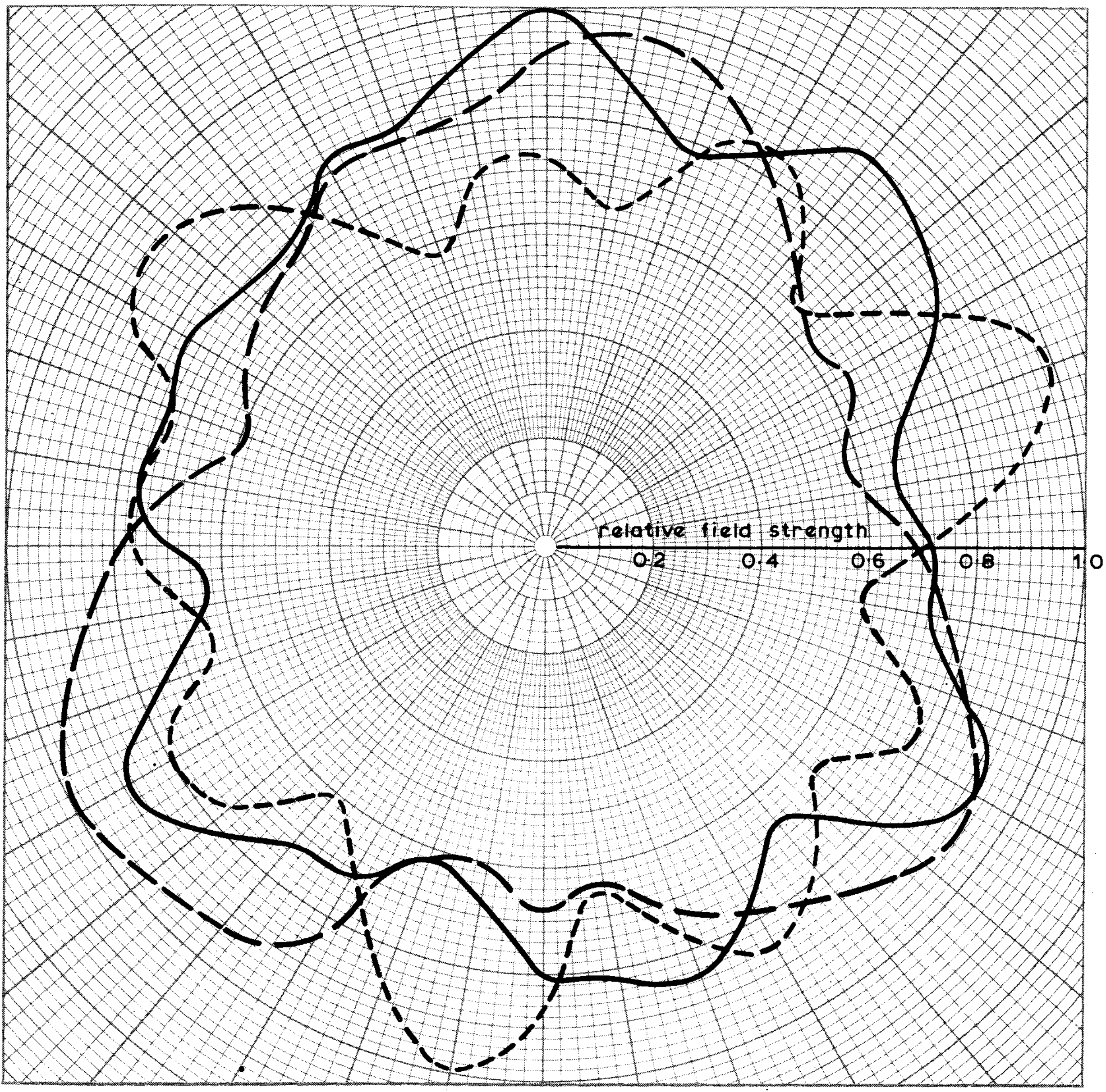

Fig. 13 - Horizontal radiation pattern of one tier of three panels in free space with phase-rotational feeds; 914 mm (3 ft) side dimension

— — — — 550 MHz ——— 650 MHz - - - - - - 750 MHz

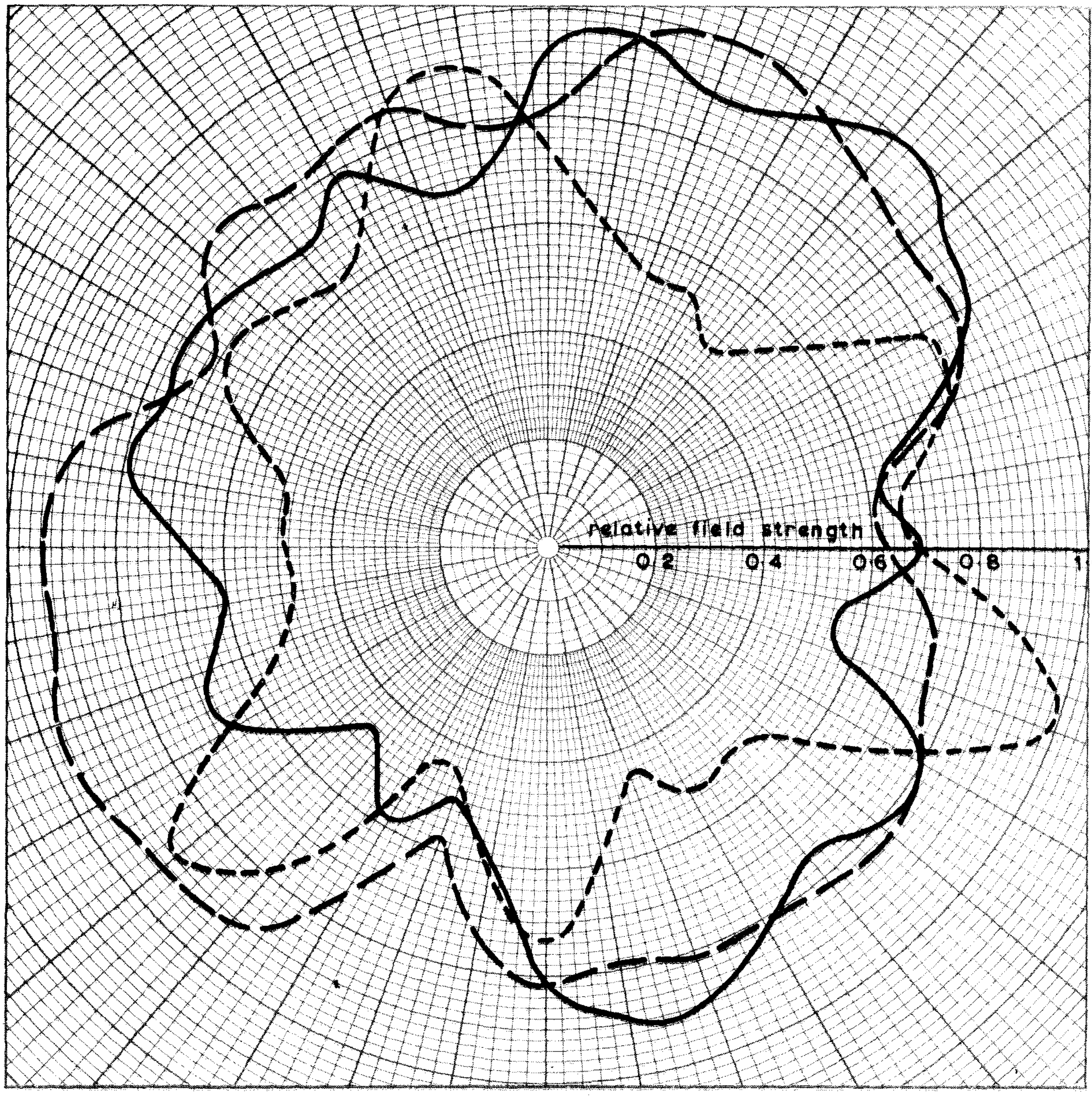

Fig. 14 - Horizontal radiation pattern of one tier of three panels in 1·52 m (5 ft) glass-fibre cylinder, with phase-rotational feeds; 914 mm (3 ft) side dimensions

— — — — 550 MHz   ———— 650 MHz   - - - - - - 750 MHz

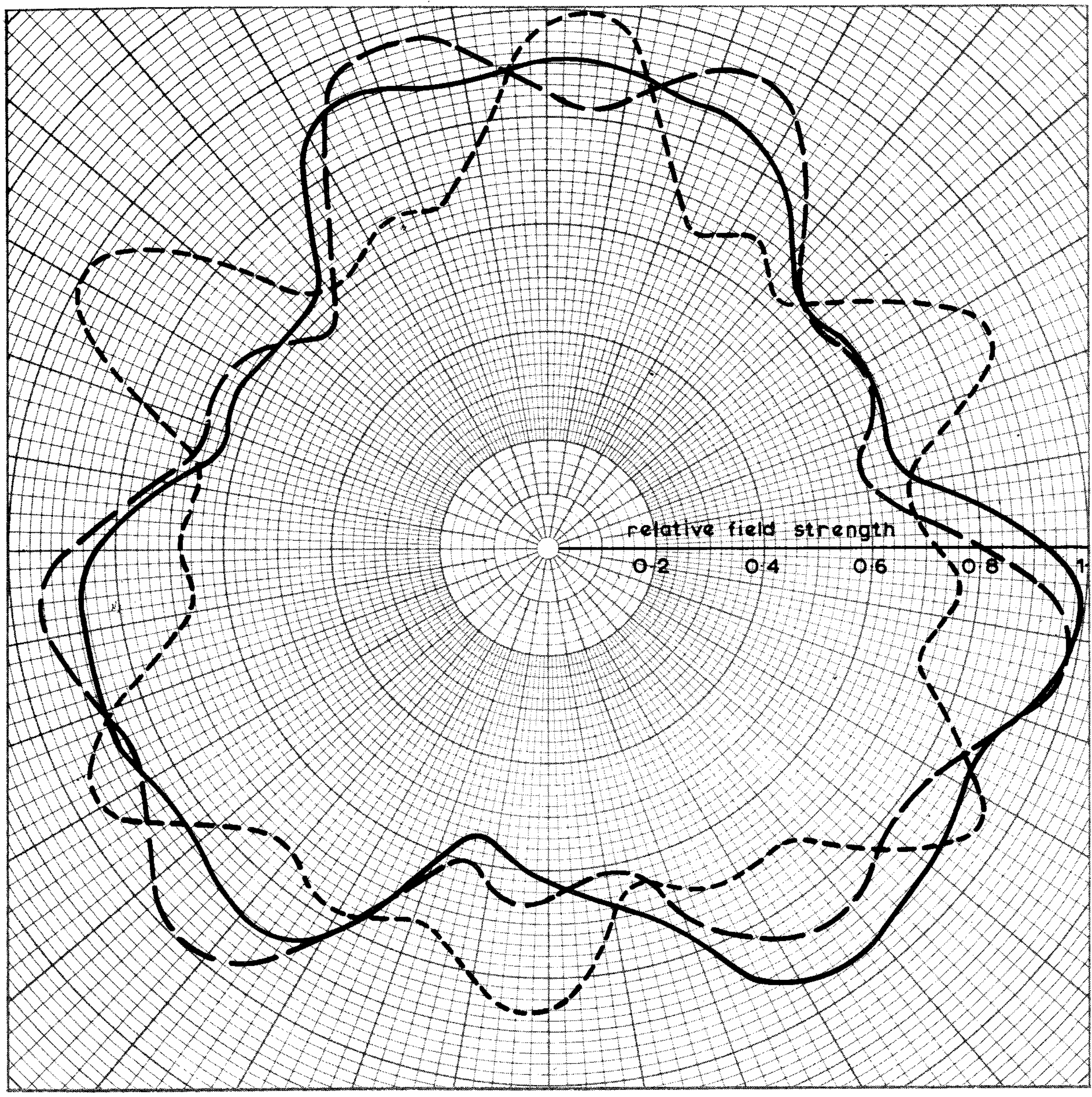

Fig. 15 - Horizontal radiation pattern of one tier of three panels in 914 mm (3 ft) diameter glass-fibre cylinder with co-phased feeds

— — — — 550 MHz ——— 650 MHz - - - - - - - 750 MHz

5. CONCLUSIONS

It is believed that the aerial panel could be produced cheaply and accurately. It is well matched over a wide frequency range and is capable of handling moderate powers. Use of the panel in a triangular configuration with co-phased feeding gives omnidirectional patterns with uniformity limits better than ± 2·5 dB over acceptable frequency ranges. With polyphase feeding the uniformity of the h.r.p. was poor, especially when the aerial was surrounded by a large glass-fibre cylinder, and it would therefore be better to employ impedance compensation over the vertical aperture.[1,4]

It is confidently expected that the aerial panel would be equally suitable for use in a square configuration, but no h.r.p. measurements were made for this case.

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